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PLANAR LIGHT SOURCE DEVICES

CLAIM(S)

1) A planar light source device comprising a light source, a photo-conductor with its incident end surface positioned near the light source, a light diffusion section made on the front surface of the photo-conductor, and a reflection surface made on the back surface of the photo-conductor, characterized in that said light diffusion surface consists of two diffusion surfaces positioned with an air space between them.

2) A planar light source device, as cited in Claim 1, wherein said light diffusion section consists of diffusion surface and of transparent sheet whose front surface is saw-shaped in its sectional view.

3) A planar light source device, as cited in Claim 1 or Claim 2, wherein said photo-conductor is made of transparent resin whose refraction index n is n 1.45.

DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a planar light source device using a photo-conductor that is used for a back light of a liquid display device.

(Prior Art)

The prior art planar light source device using a photo-conductor has such a structure as that shown in Fig. 3. More specifically, it comprises light source 1, photo-conductor 2 with its incident end surface positioned near the light source, diffusion surface 3 made on the surface of photo-conductor 2, and reflection surface 4 made on the back surface of the photo-conductor 2. While the light from the light source is entering from the incident end surface into the photo-conductor 2 and is being conducted through the photo-conductor to the side opposing to the incident end surface while being reflected at the front and back surfaces, the light is partially passing through the diffusion surface 3 and going out in form of the diffusion light. Thereby, the planar light source projects the evenly diffused light from the diffusion surface.

(Problems of the Prior Art to Be Addressed)

With the prior art planar light source device using the photo-conductor thus structured, however, the light from the light source 1 comes in from the incident end surface at any incident angle, as shown in Fig. 3, and advances while being reflected at the front and back surfaces of the photo-conductor, so the most intense light that passes through the diffusion surface 3 is the light that has an inclination angle against the diffusion surface 3. Therefore, problems arise that the brightness level is higher in the inclined direction to the diffusion surface 3 than in the direction perpendicular to the diffusion surface 3, and an image viewed from the inclined

direction is brighter than the image viewed from the perpendicular direction.

The inventors, after having experimented, found that the brightest level of the light demonstrated was in the direction of γ value, which is nearly 75° (74.6°), (as shown in Fig. 3), in case when the planar light source device has a structure shown in Fig. 3 and when the material of the photo-conductor is a transparent acrylic resin with refraction index 1.50.

The objective of the present invention is to present a planar light source device using a photo-conductor that produces the brightest light in the perpendicular direction to the diffusion surface and enables the viewers to view the brightest images from the perpendicular direction.

(Means to Solve the Problems)

The planar light source device of the present invention comprises a light source, a photo-conductor with its light source positioned near its incident end surface, a diffusion surface section made on the surface of the photo-conductor, and a reflection surface made on the back surface of the photo-conductor, and said diffusion surface section consists of two diffusion surfaces positioned with an air space between them. Because of there are two diffusion surfaces, the light going out of the photo-conductor at angle is diffused once by the first diffusion surface on the side of the photo-conductor and again diffused by the second diffusion surface. Therefore, the diffused light becomes relatively uniform, unlike the prior art one wherein the brightness was the highest in the diagonal direction, and the brightness

level and the produced images are improved in the perpendicular direction to the diffusion surface.

If the second diffusion surface of the diffusion surface section is replaced with a saw-shaped transparent body in the planar light source device having the aforementioned structure, the brightness level of the photo-conductor surface can be made higher in the perpendicular direction to the diffusion surface. As explained later in Embodiment Example 2, it is also possible to provide the first diffusion surface with a function similar to the function of the second diffusion surface thatis a refraction function of the saw-shaped section of said transparent body, to improve the brightness level in the direction perpendicular to the diffusion surface. In such a case, the back surface of the transparent sheet having the saw-shaped surface may be processed to provide the diffusion function and this diffusion surface may be positioned to face the photo-conductor surface to use this back surface as the first diffusion surface. By this, the light from the photo-conductor surface is diffused at the first diffusion surface when passing through the transparent body, is refracted at the saw-shaped section having a function similar to the second diffusion surface, and is directed in the direction perpendicular to the diffusion surface.

By thus combining the first diffusion surface with the saw-shaped section, the brightness level can be maximized in the perpendicular direction to the diffusion surface as if two sheets of diffusion sheets were used.

Moreover, the planar light source device uses a material with a low material

quality [sic; perhaps misprint for low refraction index ?] for the material constituting the photo-conductor, so the inclination angle of the light coming out of the photo-conductor surface is minimized. In addition, by two diffusion surfaces, or the first diffusion surface and the second diffusion surface with the saw-shaped section, the impact on the light caused by the inclination angle is eliminated, so the light becomes brighter in the perpendicular direction with even distribution.

(Embodiment Example)

The present invention is further explained below with reference to the embodiment examples and drawings.

Fig. 1 shows a sectional view of the first embodiment example of the planar light source device of the present invention. In the figure, 1 indicates the light source, 2 the photo-conductor, 3 the diffusion surface section, and 4 the reflection surface. The diffusion surface 3 has, unlike the prior art one, two sheets of diffusion surface: the first diffusion surface 5; the second diffusion surface 6.

In this embodiment examples of the present invention, the light diagonally going out of the photo-conductor 2 is diffused at the first diffusion surface 5, and this diffused light is again diffused at the second diffusion surface 6.

The light diffused at the first diffusion surface 5 is brightest in the inclined direction to a certain degree like that in the prior art device shown in Fig. 4 but, since the light is diffused into every direction, the intensity of the light is weaker than it was when it came out of the photo-conductor. Since the diffused light is

again diffused at the second diffusion sheet, the brightness of the light is uniform in every direction, so the brightness level is highest in the direction perpendicular to the diffusion surface.

The result of the experiment conducted by using the planar light source device of the embodiment example of Fig. 1 showed that the brightness level in the direction perpendicular to the diffusion surface was increased by 25% relative to the prior art one.

Fig. 2 shows the second embodiment example of the present invention, wherein the second diffusion surface is replaced with the transparent saw-shaped surface. More specifically, the first diffusion sheet 5 was positioned on the surface of the photo-conductor 2, and further on top of it, is positioned the transparent sheet 7 whose one surface is saw-shaped.

In this embodiment example, the surface 7a of the transparent sheet 7 that is positioned on the opposite side to the photo-conductor side is saw-shaped and has a function similar to that of the second diffusion surface. Accordingly, the light going out of the photo-conductor 2 is once diffused at the first diffusion sheet 5 and, subsequently, most part of it is directed upward by the saw-shaped section 7a, so the brightness level in the perpendicular direction to the diffusion surface is increased.

As a result of the experiment conducted by using the device of this embodiment example, it was found that the brightness level was increased by 50% in

the direction perpendicular to the diffusion surface.

In the second embodiment example, if the planar surface 7 b of the transparent sheet 7 is processed to be roughened and used as the first diffusion surface, the diffusion sheet 5 can be omitted.

If multiple transparent sheets having a saw-shaped section are used in the second embodiment example, the brightness level can be further increased in the direction perpendicular to the diffusion surface. But, this will require more number of parts and result in higher cost.

As to the saw-shape of the transparent sheet 5 in the second embodiment example, a variety of shapes can be considered. For example, θ_1 and θ_2 shown in Fig. 2 can be $\theta_1 = \theta_2$, $\theta_1 < \theta_2$, or $\theta_1 > \theta_2$. However, when there is a large difference between the values of θ_1 and θ_2, the saw-shape has an impact on the images to be viewed, which is not desirable. Accordingly, θ_1 and θ_2 are preferably equal or nearly equal. The result of the aforementioned experiment was demonstrated by using $\theta_1 = \theta_2$.

As explained above, for the prior art planar light source device of a photo-conductor, an acrylic resin is used, and the direction for the highest brightness level was 74.5°. Based on this, it can be considered that the light advancing in the photo-conductor while being reflected one after another is most intense at nearly 40° shown in Fig. 3. The angle γ at which the light with angle α goes out of the photo-conductor varies depending upon the refraction index of a photo-conductor;

provided that the α is constant, the smaller the refraction index is, the smaller the γ is.

The present invention uses this theory, so the refraction index was minimized to minimize the value of γ in order to maximize the brightness level in the direction perpendicular to the diffusion surface.

For example, when polymethyl pentene (n = 14.5) is used for the material of a photo-conductor, $\gamma = 68.8°$ holds true based on the following formula:

$$\sin \gamma = n \sin \alpha$$

More specifically, if n = 1.45 and $\alpha = 40$, $\gamma = 69°$ holds true.

The result of the experiment conducted by using said material for a photo-conductor indicated that the brightness level was highest at $\gamma = 69°$.

With the photo-conductor using a low refraction index material, the direction for producing the highest brightness level is not so much inclined from the perpendicular direction. Therefore, this photo-conductor with a low refraction index is extremely effective for the planar light source device of the present invention.

The aforementioned polymethyl pentene is merely one example of the materials, but any material can be used as long as it has high transparency, heat-resistance, and low refraction index. However, if the material satisfies $n < 1.45$, it will not be very different from an acrylic resin, therefore, is not so effective, so the material satisfying $n \leq 1.45$ is preferable.

(Advantage)

The planar light source device of the present invention produces the highest brightness level of the light in the perpendicular direction to the diffusion surface, so it enable images to be viewed to be brightest in the normal viewing direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a sectional view of the first embodiment example of the present invention. Fig. 2 shows a sectional view of the second embodiment example of the present invention. Fig. 3 shows a sectional view of the prior art planar light source device.

1. Light source
2. Photo-conductor
3. Diffusion section
4. Reflection surface
5. First diffusion surface
6. Second diffusion surface

DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a back light device primarily used for the back surface illumination for a liquid crystal display device.

(Prior Art)

A publicly known liquid crystal screen of a measuring instrument or television does not have its own light, so it needs to be illuminated by a back surface reflection sheet or back surface light source. The illumination means using the back surface reflection sheet requires the surrounding brightness by the natural light or artificial light. The means using the back surface light source does not require the surrounding light but requires a dedicated luminescent source.

The light source for this purpose is required to have even luminescent brightness over the entire display sheet, so a surface light source device such as an electroluminescent device is desired. But, when a local light source such as a small incandescent lamp or fluorescent lamp is used, a device for measuring the luminescent light is necessary.

As such a light diffusion means, the device using a photoconductor is widely used (e.g., Japanese Unexamined Utility Model Patent Applications 54-8383 and 58-10-8491).

(Problems of the Prior Art to Be Addressed)

Not to prevent a thinness, which is one of the characteristics of said liquid crystal display device, its back light device is strongly required to have a thin structure. From this standpoint, the device using said photoconductor is effective but cannot uniformly diffuse the light over a broad area. Therefore, a variety of technical apparatus including the aforementioned examples have been proposed. However, every one of these prior art apparatus comes with problems. The device having a photoconductor with a unique curved surface or the device treated with masking for controlling the light transmission that requires designing and processing results in high cost, and a uniformly assembled product is not easily accessible due to uneven performance and parts including a light source bulb.

Under these circumstances, the present invention was produced with an attempt to improve a back light using a photoconductor that allows to obtain a simply structured thin and uniform product appropriate for mass production.

(Means to Solve the Problems)

To accomplish this objective, in the back light device of the present invention, a reflecting coating material is directly coated on the back surface of the photoconductor made of plastic or glass excluding a narrow zone along the end surface on the incident side, and roughness or grooves are created in the surface in the front surface that opposes to said coated surface.

Also, the reflection coating is coated on the side surfaces other than said incident side surface, which make the device more effective, and the light incident side surfaces are perpendicular to the front surface. A light-absorbing sheet such as a black delustering sheet is preferably applied to the zone where said reflection coating is not coated, or if necessary, an opaque light diffusion sheet may be placed on the front surface of the photoconductor with a space between them.

(Operation)

The photoconductor made of plastic material that receives the incident light from the side surface allows, by the reflection index of the plastic material, that the incident light having an angle higher than its critical angle advances without letting the light emit from the front and back surfaces.

The roughness on the surface of the photoconductor reflects the incident light having an angle close to its critical angle at random, so part of the reflected light goes out of the front surface while being simultaneously reflected toward the back surface by changing the reflection angle. By the light-reflection coating directly coated on the back surface of the photoconductor, the light reflected at said back surface is reflected again and advances toward the front surface. Since the reflection angle of the guided light reflected again at the front and back surfaces becomes an acute angle smaller than said critical angle, so the rereflected light heading to the front surface goes out of the front surface.

On the other hand, in the zone along the incident side surface of the photoconductor where the light reflection coating is not coated, the guided light out of the incident light that has a lesser critical angle is emitted from the front and back surfaces. The narrow zone functions as a filter to regulate the angle of the incident light into the photoconductor to a specific range (the angle larger than the critical angle in said coated area).

As a result, most of the incident light into the photoconductor goes through the repetition of the aforementioned rereflection function and is emitted in form of the light with a nearly equal light path from the photoconductor. By this light, uniformly bright light can be produced over the illumination surface.

(Embodiment Example)

Fig. 1 shows a perspective view of the device as one embodiment example of the present invention, and Fig. 2 shows its sectional view indicating that window 2 is made in the top surface of the non-transparent outer casing 1.

On the other hand, 3 indicates the photoconductor made of transparent thick sheet such as a glass or plastic sheet. On its one side surface, a tubular fluorescent lamp 4 having nearly same thickness as that of the casing body 1 and a small diameter is placed. On the top surface of the photoconductor 3, light diffusion sheet 5 made of opaque thin sheet such as a milky white color sheet is placed under the separator 6 to face said window 2.

On the top surface of said photoconductor 3, small projections in strip form 7 are positioned at random to roughen the surface. The other three end surfaces excluding the bottom surface and the incident end surface 8 where said fluorescent lamp 4 faces are coated with light-reflecting coating 9 made of white paint, which is shown by its partially expanded view in Fig. 3. As shown in Fig. 3, said incident end surface 8 is made to be perpendicular to said top surface, and the zone 3a along the end surface 8 is not coated with said coating 9. On the top and bottom surfaces of the zone 3a, light-absorbing sheet 10 such as a black delustering sheet is overlapped. And, 11 indicates a reflection sheet applied to the back surface of said fluorescent lamp 5, 12 a member for the lamp lighting circuit, and 13 an electrical power input terminal.

Another embodiment example of the present invention is not shown in the figure, but it is possible to use the light diffusion surface which is roughened by forming many small pyramids or narrow grooves. In addition, the density of the concavities and convexities constituting the roughened surface may be gradually made higher as the surface gets farther from the incident end surface 8. Also, the prior art method wherein the top and bottom surfaces formed into a curvature may be combined with said method. It is also possible to use a multiple light type wherein the opposing end surfaces of the photoconductor 3 are used as the incident end surfaces. In the embodiment example using such a structure, the major surface of the photoconductor 3 (equivalent to said window 2) can be made into a single

light type with an A5 size or a multiple light type with an A4 size, and its thickness can be 10 mm or less including the casing thickness in either instance. Once an external low voltage direct current power source is connected to terminal 12 at a time of using, arc light lamp 4 is lit by a lighting circuit structured in form of an inverter consisting of parts of the lighting circuit integrated in its body. The illumination light lit by the lamp 4 is guided from the incident end surface 8 into the photoconductor 3 by the operation of the reflection sheet 11 on the back side and advances through the photoconductor 3.

This directly advancing light is the light came out of the arched surface of the fluorescent lamp 4 on the incident end surface 8, so the direct linear direction is changed into multiple directions (shown by dotted lines in Fig. 2). First, the light ray having a large incident angle for the incident end surface 8 is reflected at surface 8 and is prevented from going into the photoconductor 3. The ray having an angle close to the incident angle capable of coming into the surface 8 goes into the photoconductor 3 once but is emitted from the top or bottom surface of said zone 3a for its incident angle being large and is absorbed by the light-absorbing sheet 10 placed in the area. Accordingly, most of the light guided into the photoconductor 3 becomes the directly advancing light having an angle smaller than the critical angle of the top and bottom surface in the region coated with said incident coating 9. Therefore, if the top and bottom surfaces of the photoconductor 3 are smooth surfaces in parallel, the light will not be emitted from both surfaces. With this

embodiment example, however, the top surface is roughened, and the guided light hitting the top surface is refracted. By this refraction, the guided light whose incident angle is less than the critical angle to the bottom surface passes through the bottom surface but is reflected at the light-reflection coating 9 coated on the bottom surface. Since the bottom surface and light-reflection coating 9 do not have an air film layer, the reflected light again goes into the photoconductor 3 with nearly the same reflection angle as said incident angle and is emitted from the opposing top surface. It goes without saying that part of the light may be reflected at the roughness structure on the surface but, for most part, the light goes through the repetition of reflection and incidence while receiving reflection from the three side surfaces of the photoconductor 3, and is emitted from the top surface.

More specifically, the guided light whose guiding angle is limited to a relatively narrow angle by the operation of the zone 3a very close to the light source hardly emits directly from the major surface of the photoconductor 3. Therefore, an inappropriate brightness level of the surface near the light source of the photoconductor 3 can be prevented. Also, since most part of the light emitted from the front surface repeats the reflection more than twice and since the reflection adds some light scattering effects to these reflections, the total light path lengths of the guided light are averaged out evenly and the light intensity after the light path attenuation becomes more uniform. As a result, the brightness level on the major surface of the photoconductor 3 can be made uniform.

Moreover, by overlapping the light diffusion sheet 5 on said surface, said uniformly bright light can be better preserved.

(Advantage)

Unlike the prior art device, wherein the generation of uneven brightness that tends to occur to the incident end surface and the uneven brightness in the broad region of the photoconductor were prevented by a complex curved structure of the bottom reflection sheet or by using a unique filter with different light transmission coefficients on the top and bottom surfaces of the photoconductor, in the device of the present invention that has a structure for taking the incident light from one side surface, the emission light from the top surface becomes the reflection light reflected more than twice in the photoconductor by not coating the narrow zone near the incident end surface of the photoconductor, limiting the incident angle of the guided light to a specific range in an attempt to improve the emission of the guided light from this zone, roughening the surface of the photoconductor, and by coating the bottom surface with reflection coating. So, the light path lengths of the emission light are averaged in the photoconductor, by which the brightness level on the major surface can be uniform. The device is simple in its structure and appropriate for mass production, by which uniform products can be presented at low cost. The device is extremely excellent in performance and can be formed thin, therefore, is extremely useful as a back illumination means for a liquid crystal display device.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a perspective view of the device as one embodiment example of the present invention. Fig. 2 shows a sectional view of the A-A section of Fig. 1. Fig. 3 shows a partial perspective view of the embodiment example of the present invention.

1. Body
2. Window
3. Photoconductor
4. Fluorescent lamp
5. Light diffusion sheet
7. Small projection in strip form
8. Incident end surface
9. Light-reflection paint
10. Light-absorbing sheet